UNIVERSITY OF TECHNOLOGY SYDNEY
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Dynamic Spectrum Sharing and Coexistence with Full-Duplex Device-To-Device Communications in 5G Networks

by

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CERTIFICATE OF ORIGINAL AUTHORSHIP

I, Noman Haider declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy (PhD), in the School of Electrical and Data Engineering, Faculty of Engineering and Information Technology at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise reference or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

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ABSTRACT

Opportunistic Spectrum Access has recently become the most desirable solution for greatly improving the performance of telecommunication systems. It has proven to be a viable solution to cope with the challenging problem of spectrum scarcity and also it has been widely explored in 5G networks, so that multiple random access technologies can coexist in a cognitive setup. In 5G networks, such secondary technology candidates like Device-to-Device (D2D) communications, and Licensed-Assisted Access are envisioned to opportunistically exploit spectrum opportunities and coexist with primary technologies like LTE or WiFi. Moreover, Full Duplex (FD) technology is envisioned to play a significant role in 5G networks by allowing a user to transmit and receive on the same frequency band.

In this thesis, we present a comparative performance analysis of the spectral efficiency in a heterogeneous system where a cellular network allows the FD-Enabled D2D network to use opportunistically its spectrum while ensuring protection for its transmission/reception through guard zones. The main contributions and emphasis of this work are to explore the spectrum opportunities for secondary users by: firstly, deriving their probability of successful transmissions, deciding the feasible mode of operation (half-duplex, full-duplex or silent); and secondly, incorporating the protection zone for primary users. We assess the overall system performance, analyze the impact of different access mechanisms and propose an efficient mode selection for secondary users.

Such a systematic analysis of the integrated technologies requires a rigorous and critical evaluation of the performance gains and the costs incurred in terms of increased interference. Also, ultra-dense and random network models are envisioned in future networks especially in the urban scenario, hence, pre-deployment average system performance over various deployment scenarios can in fact be advantageous. In this thesis, we use stochastic geometry to model and analyze different coexistence scenarios and spectrum sharing frameworks in 5G networks for multiple radio access

technologies. We also assess different coexistence methodologies for secondary users to fairly and peacefully coexist with primary users while ensuring the interference protection for primary users.

In summary, FD enabled heterogeneous networks have not been critically studied in previous literature, and for this reason a comprehensive study on the use of FD to existing systems is needed. This thesis proposes an innovative FD enabled D2D cognitive setup and carefully studies the improvement in system performance while taking into account the cost of these gains in 5G networks, using stochastic geometry tools.

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List of Publications

Journal Papers

J-1. **Noman Haider**, Ahsan Ali, Cristo Suarez-Rodriguez, Eryk Dutkiewicz, "Optimal Mode Selection for Full-Duplex Enabled D2D Cognitive Networks", *IEEE Access*, 2019.

J-2. Cristo Suarez-Rodriguez, **Noman Haider**, Ying He, Eryk Dutkiewicz, "Network Optimisation in 5G Networks: a Radio Environment Map Approach", in *IEEE Transactions on Vehicular Technology*, 2019 (Submitted).

Conference Papers

C-1. **Noman Haider**, Ahsan Ali, Ying He and Eryk Dutkiewicz, "Performance Analysis of Full Duplex D2D in Opportunistic Spectrum Access," 18th International Symposium on Communications and Information Technologies (ISCIT), Bangkok, 2018, pp. 32-37.

C-2. **Noman Haider**, Eryk Dutkiewicz, Diep N. Nguyen, Markus Mueck, Srikathyayani Srikanteswarae, "The Impact on Full Duplex D2D Communication of Different LTE Transmission Techniques," IEEE 85th Vehicular Technology Conference (VTC Spring), Sydney, NSW, 2017, pp. 1-5.

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Abbreviation

2D - Two-dimensional

3GPP - 3rd Generation Partnership Project

BS - Base Station

CA - Carrier aggregation

CS - Carrier Sense

CBRS - Citizen Broadband Radio Service

CSMA - Carrier Sense Multiple Access

D2D - Device-to-Device

EZ - Exclusion Zone

FD - Full-Duplex

GZ - Guard Zone

HD - Half-Duplex

LAA - Licensed Assisted Access

LSA - Licensed Shared Access

LTE - Long Term Evolution

M2M - Machine-to-Machine

MNOs - Mobile Network Operators

MHPP - Matern Hardcore Point Process

OSA - Opportunistic Spectrum Access

PHP - Poisson Hole Process

PPP - Poisson Point Process

PU - Primary Users

RAT - Random Access Technologies

RX - Receiver

SAS - Spectrum Access System

SG - Stochastic Geometry

SIPR - Self-Interference-to-Power-Ratio SU - Secondary Users

TX - Transmitter

UDN - Ultra-dense Networks

WiFi - Wireless Fidelity